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DIFFERENTIAL SENSITIVITY FOR SOMESTHETIC PRESSURE*

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The data published by Stratton (19) and others (2, 8, 10, 17, 20, 23) show that differential sensitivity for somesthetic pressure ($=1/\Delta P$) varies inversely with the applied mechanical pressure (P in gm./cm.^{2}) when the area of surface in contact with a given region of the skin is held "constant" (*cf.* Fig. 1). For a constant area, $\Delta P = K\Delta W$. In terms of a neurophysiological theory (11, 12, 13) this means that $1/\Delta P$ decreases because the number of elements available for the discrimination has been made to decrease. A specific consequence of this theory is that differential sensitivity for constant mechanical pressure should increase when the stimulating area is increased, even though the total weight is increased proportionately with the area. The experiments of Weber (23), Hering (10), and Stratton (19) do not furnish information concerning the status of this prediction. The purpose of the experiment reported here is to provide information for its evaluation.

The particular region selected for stimulation was located about one-third of the distance from the elbow to the wrist on the volar aspect of the left forearm. To reduce the likelihood of disturbing factors, the arm, after being shaved, was fitted snugly but comfortably into an especially prepared plaster cast and was completely relaxed during each stimulation. A method of limits was employed (continuous change in the direction of increase).

Six containers, appropriately loaded, served as standards for stimulation. These vessels were constructed of thinly drawn glass, cylindrical in form. They were prevented from tipping by means of adjustable guides. Their circular cross-sections varied in area, but each exerted the same pressure ($=6$ *gm./cm.*^{2}) on the arm. The bottom of each vessel was covered with mat-surface cardboard. Five seconds after the circular base of a vessel had been carefully placed in contract with the surface of the arm, the total weight was increased at the constant rate of 1 *gm./sec.* by adding water from a calibrated

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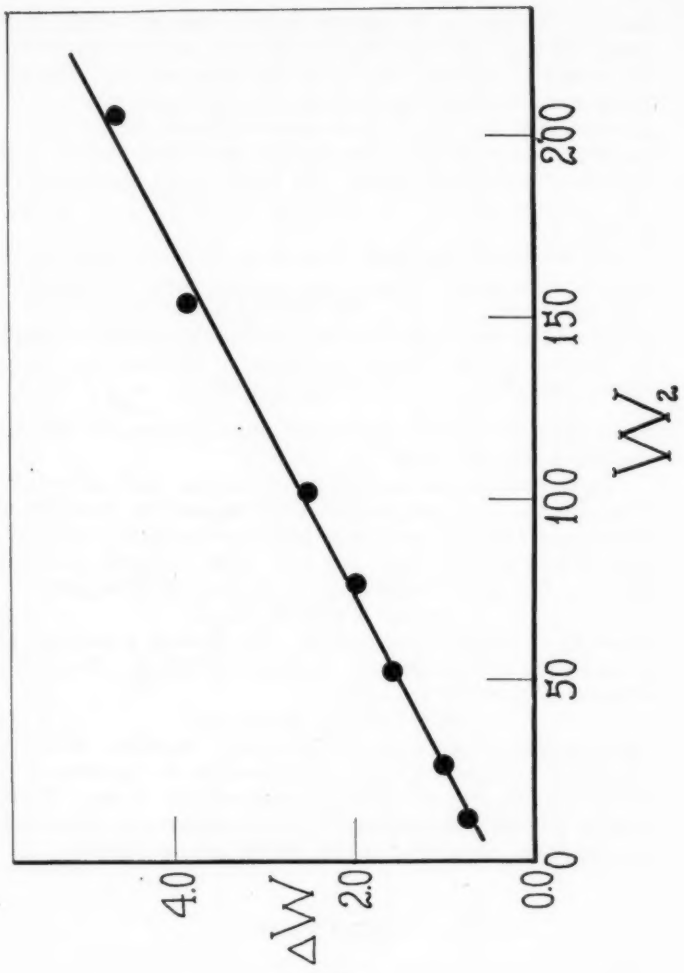

FIGURE 1

Illustrating the relation ΔW and W_2 for somesthetic pressure; ΔW and W_2 are measured in grams. Data from Stratton (1896) for four observers. Each shaded circle is an average of 20 measurements. The area of the surface of application is a parameter, and the applied weight is directly proportional to mechanical pressure, P (in gm./cm.^{2}). A method of limits was used (continuous change in the direction of increase). ΔW ($= K\Delta P$) is an approximately rectilinear function of the adjusted weight, W_2. The solid line has a slope = 1:50.

burette. As soon as the observer signified that the weight of the object had been just noticeably increased, the experimenter recorded the number of grams required to eventuate the response. Introspectively, it was reported that the judgments were made in terms of an increase in the intensity of the somesthetic pressure localized beneath the object and in the arm. Ten readings were taken for each of the six areas during a single sitting. The results for six sittings taken on six consecutive days for the same observer (A.H.H.) are presented in Table 1.

Each ΔP entry in the Table is based on ten measurements for one observer. Mechanical pressure and exposure time are parameters; area and weight, variants. The first and second columns give the weight and the area of the standard stimulus; the mechanical pressure P_1 (column 3) was constant throughout. The next six columns contain the ΔP_m values for the six experiments. $\sigma_{\Delta P}$ = the root-mean-square deviation of a single observation; its properties have been considered elsewhere (14).

Fig. 2 shows the net result of the experiment. Each point (ΔP_m) is an average from sixty measurements obtained by averaging the six mean ΔP's for each area. Logarithmic coordinates are used. ΔP is seen to decrease as A (and, therefore, as W) is made to increase. The solid line drawn in the figure is described by the equation

$$\log \Delta P = -K \log A + \log C \qquad (1)$$

where $K(= 1.1)$ and C are constants. The equation is empirical and is used solely to epitomize the experimental findings. In terms of differential sensitivity $(= 1/\Delta P)$,

$$\log (1/\Delta P) = K \log A + \log C \qquad (2)$$

The logarithm of differential sensitivity for intensitive increase in somesthetic pressure is a rectilinear function of the logarithm of the stimulating area over the range of magnitudes of A used. Corresponding data for retinal excitation (*cf.* 18) suggest that over a wider area range the curve (Fig. 2) may become concave upward.

DISCUSSION

When the area of the surface of application is constant, differential sensitivity is known to vary inversely with mechanical pressure P_1 (*cf.* 19) and hence also to vary inversely with the standard weight W_1. It might be argued, therefore, that differential sensitivity varies *inversely* with the total excitation produced. That this view cannot

TABLE I.

W (gm.)	A (cm.²)	P_3 (gm./cm.²)	1 $\Delta P \pm \sigma_{\Delta P}$	2 $\Delta P \pm \sigma_{\Delta P}$	3 $\Delta P \pm \sigma_{\Delta P}$	4 $\Delta P \pm \sigma_{\Delta P}$	5 $\Delta P \pm \sigma_{\Delta P}$	6 $\Delta P \pm \sigma_{\Delta P}$
75.36	12.56	6.0	0.339 ± 0.056	0.364 ± 0.13	0.255 ± 0.054	0.317 ± 0.069	0.36 ± 0.108	0.45 ± 0.089
51.6	8.6	6.0	1.002 ± 0.147	0.647 ± 0.152	0.514 ± 0.058	0.526 ± 0.053	0.71 ± 0.09	0.63 ± 0.07
18.84	3.14	6.0	2.43 ± 0.732	1.809 ± 0.213	1.503 ± 0.439	1.497 ± 0.226	1.68 ± 0.535	2.07 ± 0.5
6.78	1.13	6.0	8.21 ± 2.079	7.805 ± 2.381	5.894 ± 0.615	4.726 ± 2.15	5.75 ± 0.71	6.5 ± 0.902
3.84	0.64	6.0	12.656 ± 3.609	8.813 ± 0.92	9.813 ± 2.234	7.688 ± 1.688	7.28 ± 2.77	5.81 ± 2.03
2.46	0.41	6.0	23.4 ± 2.64	18.6 ± 2.05	21.9 ± 3.17	10.5 ± 0.96	19.7 ± 3.20	21.7 ± 3.33

Results for six sets of experiments taken on six successive days for one observer. Each entry is based on ten measurements. ΔP_m stands for a just noticeable increase in somesthetic pressure; $\sigma_{\Delta P}$ is the root-mean-square deviation of a single observation.

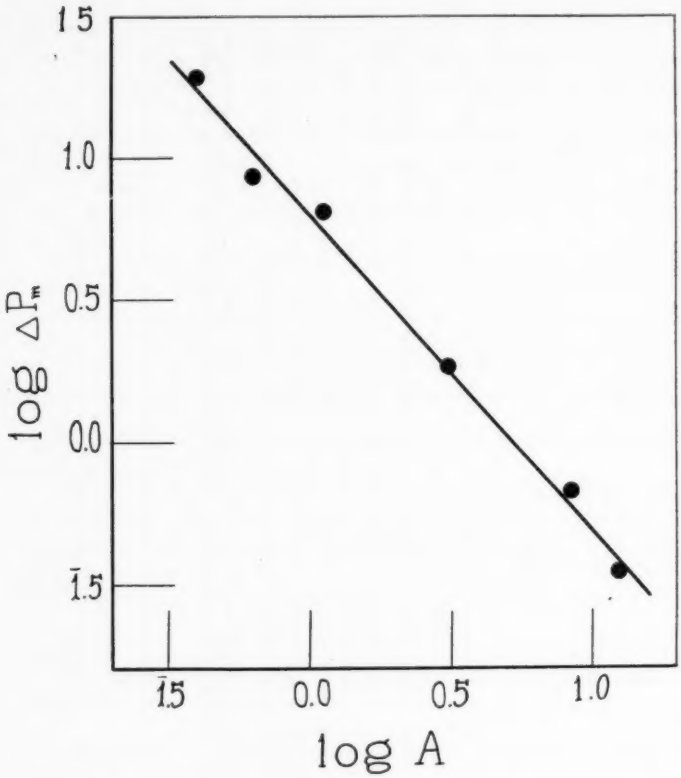

FIGURE 2.

Showing the relation between ΔP and area A for somethetic pressure. Mechanical pressure (= 6 gm./cm.^{2}) and exposure time (= 5 secs.) are parameters; area and weight, variants. Each point is based on 60 measurements for one observer.

possibly be correct in general, however, is demonstrated in the present experiment. $1/\Delta P$ is shown here to vary *directly* with the applied weight and thus with the strength of the corresponding excitation. Any attempt to correlate differential sensitivity simply with the magnitude of the sensory excitation, therefore, can lead only into contradiction. The same discrepancy exists for the discrimination of sensory intensities in other departments of sense (3, 4, 7, 9, 13, 16, 18, 21, 22).

A resolution of this discrepancy can be achieved in terms of a neurophysiological theory: differential sensitivity ($1/\Delta P$) is said to depend upon the number of elements of excitation potentially available for the discrimination in question (11, 12). As regards somesthetic pressure, for area and exposure time as parameters, the number of elements potentially available for the discrimination decreases as the mechanical pressure increases; so does differential sensitivity (*cf.* 19). When mechanical pressure and exposure time are parameters, as in the present experiment, the number of elements potentially available for the discrimination under these conditions is also increased as area is increased; our results demonstrate that differential sensitivity does likewise. Differential sensitivity is thus seen to vary directly, though not necessarily in direct proportion, with the number of elements potentially available for the discrimination. This theory is in a sense the *supplement* of the "volley theory" (1) of sensory intensity.

SUMMARY

Data from classical experiments show clearly that differential sensitivity for somesthetic pressure varies *inversely* with the applied weight when the stimulating area is constant. Data from the experiments reported in the present paper, however, demonstrate that, for mechanical pressure as parameter (= 6 *gm./cm.*^{2}) and area as variant, differential sensitivity varies *directly* with the applied weight. These results are shown to be consistent with a neurophysiological theory of differential sensitivity.

BIBLIOGRAPHY

(1) Boring, E. G., Langfeld, H. S., Weld, H. P., et al, *Psychology*: a factual text-book. N. Y.: Wiley, 1935. Pp. xviii + 555 (Chapters 5 and 8).
(2) Bush, A. D., and Austin, A. M., Weber's Law as tested by flowing increments, *Amer. J. Psychol.*, 1924, 35, 230-234.
(3) Churcher, B. G., King, A. J., and Davies, H., The minimum perceptible change of intensity of a pure tone, *Phil. Mag.*, 1934, 18, 7th series, 927-939.
(4) Cobb, P. W., and Moss, F. K., The four variables of the visual threshold, *J. Franklin Inst.*, 1928, 205, 831-847.
(5) Crozier, W. J., On the sensory discrimination of intensities, *Proc. Nat. Acad. Sci.*, 1936, 22, 412-416.
(6) Crozier, W. J., and Holway, A. H., On the law for minimal discrimination of intensities. I., *Proc. Nat. Acad. Sci.*, 1937, 23, 23-28.
(7) Dimmick, F. L., The dependence of auditory experience upon wave amplitude, *Amer. J. Psychol.*, 1933, 45, 463-470.

(8) Gatti, A., and Dodge, R., Ueber die Unterschiedsempfindlichkeit bei Reizung eines einzelnen, isolierten Tastorgans, *Arch. f. d. ges. Psychol.*, 1929, 69, 405-426.

(9) Heinz, M., and Lippay, F., Ueber die Beziehungen zwischen den Unterschiedsempfindlichkeit und der Zahl der erregten Sinneselemente. I. *Arch. ges. Physiol.*, 1928, 218, 437-447.

(10) Hering, E., Zur Lehre von der Beziehung zwischen Leib und Seele. I. Mittheilung. Ueber Fechner's psychophysisches Gesetz, *Sitzgsber. d. kaiserl. Akad. d. Wissen. Math. Natur. Classe*, 1875, 72 (Bd. 3), 310-348.

(11) Holway, A. H., and Hurvich, L. M., On the discrimination of minimal differences in weight: I. A theory of differential sensitivity, *J. Psychol.*, 1937, 4, 309-332.

(12) Holway, A. H., Smith, J. E., and Zigler, M. J., On the discrimination of minimal differences in weight: II. Number of available elements as variant, *J. Exper. Psychol.*, 1937, 20, 371-380.

(13) Holway, A. H., and Hurvich, L. M., Differential sensitivity to white light, *J. Gen. Psychol.* (in press).

(14) Holway, A. H., and Crozier, W. J., On the law for minimal discrimination of intensities. II. *Proc. Nat. Acad. Sci.*, 1937 (in press).

(15) Holway, A. H., and Crozier, W. J., The significance of area for somesthetic differential sensitivity to pressure, *Psychol. Rec.*, 1937 (in press).

(16) Lasareff, P., Studien ueber das Weber-Fechner'sche Gesetz. Einfluss der Grosse des Gesichtsfeldes auf den Schwellenwert der Gesichtsempfindung, *Arch. f. d. ges. Physiol.*, 1911, 142, 235-240.

(17) Schriever, H., Ueber die Gultigkeit des Weberschen Gesetzes im Gebiete des Druckinns bei Moglichst verhinter Reizausbreitung, *Arch. f. d. ges. Psychol.*, 1925, 51, 137-154.

(18) Steinhardt, J., $\Delta I/I$ for human intensity discrimination, *J. Gen. Physiol.*, 1936, 20, 185-.

(19) Stratton, G. M., Ueber die Wahrnehmung von Druckänderungen bei verschiedenen Geschwindigkeiten, *Philos. Stud.*, 1896, 12, 525-586.

(20) Thouless, R. H., reported in: Houstoun, R. A., *Vision and Colour Vision*, London: Longmans, Green and Co., 1932. Pp. vii + 238, esp. pp. 35 ff.

(21) Upton, M., and Holway, A. H., On the psychophysics of hearing: I. Monaural differential sensitivity and exposure-time, *Proc. Nat. Acad. Sci.*, 1937, 23, 29-32.

(22) Upton, M., and Holway, A. H., On the psychophysics of hearing: II. Binaural differential sensitivity and exposure-time, *Proc. Nat. Acad. Sci.*, 1937, 23, 32-34.

(23) Weber, E. H., *Annot. anat. et physiol.*, Leipzig: Koehler, F. C., 1834. Pp. xv + 258.